Surface characteristics of electroless nickel plated electromagnetic shielding wood veneer

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Abstract: Wood is a kind of porous natural material with very poor electro-conductivity, and it has almost no function of electromagnetic shielding. The method of electroless nickel plating was used to produce wooden material with electrical and effective electromagnetic shielding properties. Ni-P alloy layer was obtained on wood surface. The surface feature of plated wood veneer was observed by SEM and the surface composition and microstructure of the layer under different conditions were investigated by EDS and XRD respectively. Meanwhile, the relevant surface resistivity and electromagnetic shielding effectiveness were measured. Correlations of the phosphorous content in the layer to the structure of Ni-P alloy, electro-conductivity and electromagnetic shielding of plated veneers were discussed. SEM photos showed that the surface of electroless nickel plated veneers were covered with Ni-P alloy layer entirely, which made wood veneers more like metal. At the same time, the results showed that with the decreasing of the phosphorous content in the layer, the microstructure of Ni-P alloy layer transformed to be microcrystalline and electro-conductivity and electromagnetic shielding effectiveness were improved. When the phosphorous content was less than 2.37wt pct in the layer, the microstructure of Ni-P alloy layer was microcrystalline structure and its surface resistivity and electromagnetic shielding effectiveness were nearly 0.5 Ω/□ and 55-60dB respectively.

Keywords: Wood veneer; Electroless nickel plating; Phosphorous content; Microstructure; Electromagnetic shielding

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Introduction

With the wide use of electronic equipment, the amount of electromagnetic radiation has much increased. Electromagnetic radiation causes unwanted electromagnetic interference (EMI) (Liu and Guo 2002), electromagnetic leakage and electromagnetic pollution, which is very destructive for information safety and harmful to human health. The demand of electromagnetic shielding material has increased quickly. Many electromagnetic shielding materials are manufactured from conductive composite materials to prevent or reduce electromagnetic radiation, electromagnetic leakage and electromagnetic pollution (Huang *et al.* 1997; Zhang 2003; Zhao 2001). Most use plastic composite materials. Some types of wooden electromagnetic shielding materials were reported including a laminated wood panel with a bonded metal plate, medium density fiberboard (MDF) with carbon fiber in its core, and particle board containing a metal powder such as aluminum, copper or nickel, which all had a weight disadvantage. The weight of the composite increased greatly when a metal plate or metal powder was used (Nagasawa *et al.* 1999). In this paper, electroless plating process was applied to wood veneer to coat the surface with Ni-P alloy layer in order to obtain lightweight wooden electromagnetic shielding material. This wood veneer plated with Ni-P alloy layer can be used to replace metal plate bonded with a laminated wood panel to produce electromagnetic shielding composite materials.

Japanese researchers studied the electromagnetic shielding effectiveness of wood veneer or wood fiber plated by using one kind of electroless plating solution (Nagasawa and Kumagai 1989; Nagasawa *et al.* 1990, 1991, 1992, 1994). But the surface compositions and microstructure of the layers were not discussed in their articles. An electroless plating solution different from that used by Japanese researchers was applied to obtain Ni-P alloy layer of different phosphorous content on the surface of wood veneer through controlling pH value of the plating solution. The phosphorous content in the plating layer, electro-conductivity and electromagnetic shielding of the wooden composite, the structure of Ni-P alloy layers and their relationships were discussed in this paper.

Experimental procedure

Materials

Wood veneers from *Larlix Gmelini* with M.C=0.6 mm were prepared for the study. The veneers were dried by air. According to SJ 20524-95 (Measuring method of shielding effectiveness of materials), wood veneers were made round samples with the diameter of 115 mm. In the center of the sample, there is a hole of 12 mm diameter (Fig. 1).

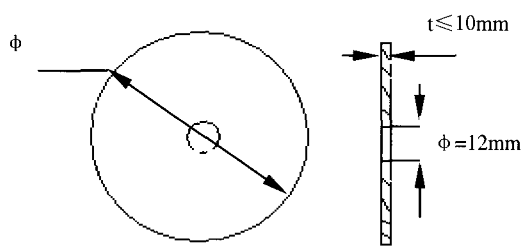

Fig. 1 Schematic of the sample

Surface treatment and addition of catalyst to wood veneers

Electromagnetic shielding wood-metal composite was pro-

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duced as the flow chart (Fig. 2). The wood veneer samples were dipped in the required concentration of Pd colloid solution of 100 mg of $PdCl_2 \cdot H_2O$ and $SnCl_2$ and an aqueous solution containing HCl and NaCl in 0.8 L of water at room temperature. The treated wood veneers were dried by hot air for 5 min and soaked in diluted HCl solution for 2 min. After that, they were taken out, washed, and dried by hot air.

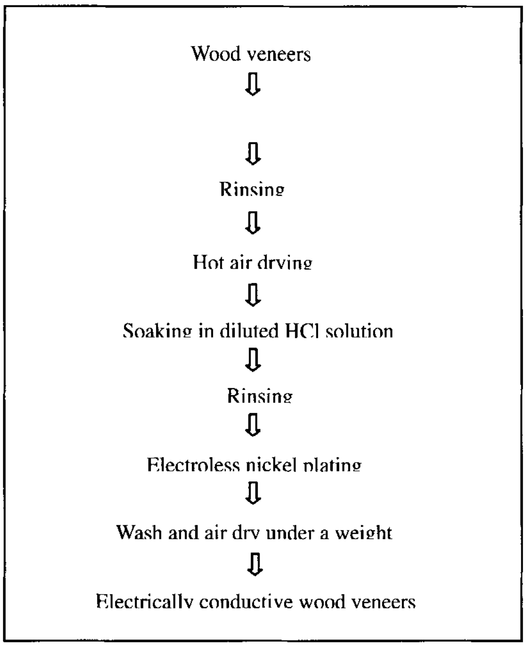


Fig. 2 Procedure of electroless nickel plating on wood veneer

Preparation of nickel plated wood veneers

Nickel plating of the wood veneers was applied by using the electroless plating technique. The plating bath was filled with nickel plating solution containing available ingredient such as a reduction agent and a complexing agent. The plating bath was filled with 500 mL of plating solution with 7–8.5 pH value and was initially set at 40 °C. The nickel plating solution consisted $NiSO_4 \cdot 6H_2O$, $NaH_2PO_2 \cdot H_2O$,complexing agent and buffering agent (Table 1). The pH value was controlled with aqueous $NH_3 \cdot H_2O$ solution during the plating. Five samples were simultaneously put into same five plating baths respectively for undergoing one plating procedure. After plated, the nickel plated wood veneers were washed with tap water and distilled water separately. And then, it was dried by air for 15 min and dried in an oven.

Table 1. Composition of nickel plating solution

Composition	Content ($g \cdot L^{-1}$)
$NiSO_4 \cdot 6H_2O$	25-35
$NaH_2PO_2 \cdot H_2O$	25-35
Complexing agent	25
Buffering agent	30

Measurement of the surface resistivity of the metallized wood veneers

The surface resistivity of the metallized wood veneers was evaluated by using the method designed according to GJB2604-96 (Fig.3). YD2511A model intelligent low resistance measuring instrument was used. The metallized sample was put on a wood plate, and two electrodes were placed on the sample under a force (G) which was set to eliminate contact resistance between the electrodes and the sample. Since wood structure is anisotropic, the plated veneers are also anisotropic in electro-conductivity. The surface resistivity parallel to fiber direction is not equal to that cross the fiber direction (Nagasawa and Kumagai 1989). Therefore, four test positions were chosen on the plated sample and the surface resistivity parallel to fiber direction and cross the fiber were measured separately on each test position. The result was the average of the surface resistivity parallel to fiber direction and that cross the fiber. The electrical resistance (R) of the plated sample was measured and the surface resistivty (R_S) was calculated using the Equation (1).

$$R_S = R / L \times 0.3 \tag{1}$$

where R_S is the surface resistivity ($\Omega/\square$), R is the electrical resistance (Ω), L is the length between the two electrons and 0.3 is the diameter of the electrons used in this study (cm).

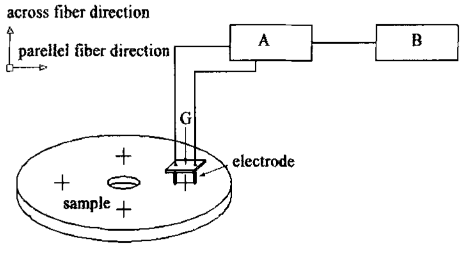


Fig.3 Schematic of measuring surface resistivity

A: Intelligent low resistance measuring instrument B: Personal computer

Shielding effectiveness measurements for electro-conductive metallized wood veneers

The shielding effectiveness of the electro-conductive wood veneers was measured by using the method of SJ20524-95. The system chart of the apparatus for measuring the electromagnetic shielding effectiveness was shown as Fig. 4. Angilent E4402B spectrum analyzer and standard butt coaxial cable line with flange were used to detect the generation of incidence electromagnetic waves and the transmission of electromagnetic waves. The frequency response was detected with frequencies ranging from 9kHz to 1.5GHz. The shielding effectiveness (SE) of plated veneers is defined as the ratio of the power transmitted through the plane to power incident on that plane, and is usually expressed in decibels (dB), as Equation (2)

$$SE = -10\lg(P_{out} / P_{in})(dB) \tag{2}$$

where P_{in} is the incident power, and P_{out} is the transmitted power.

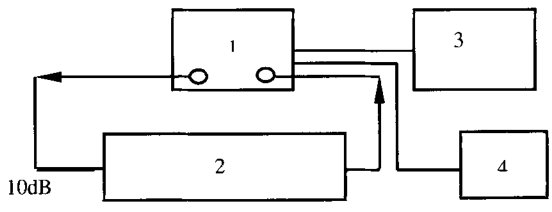


Fig. 4 System of apparatus for measuring shielding effectiveness

1 Spectrum analyzer, 2 standard butt coaxial cable line,
3 Personal computer, 4 Printer

Surface feature and determination of phosphorous content of the surface of plated veneer

The plated veneer was cut into small pieces of 4mm×4mm for surface feature and composition analyses. The surface feature was observed through scanning electron microscopy of model HITACHI-4700A without spraying C or Pt because the plated veneer was electrical. And phosphorous content in nickel deposition was determined by energy dispersion spectrometer of model EDAX integrated into the scanning electron microscopy.

Analysis of the microstructure of the plating layers on the surface of plated veneers

The plated veneer pieces of 15 mm×15 mm were used to analyze the microstructure of plating layer by model D/MAX-3B X-ray diffractometer (Rigaku).

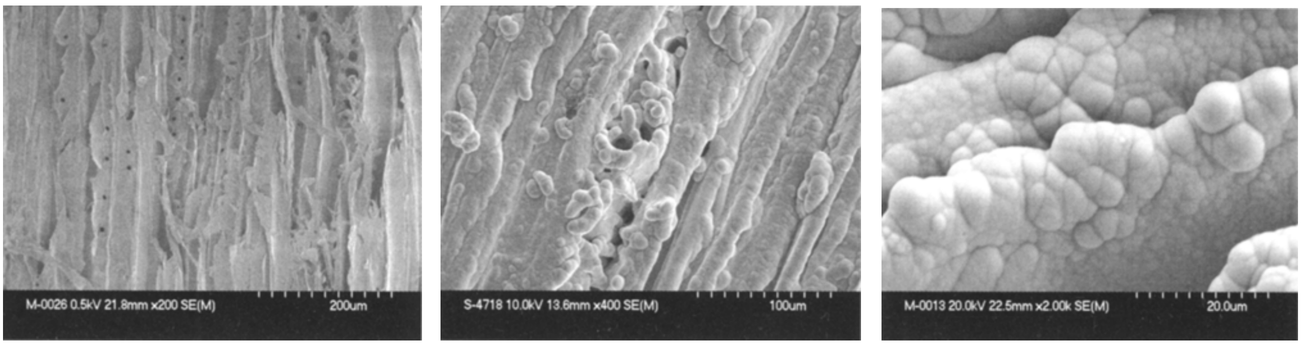
Results and discussion

The feature of the surface of plated veneer

The surfaces of un-plated and plated veneers are shown in Fig. 5. Micrograph A shows the profile of the surface of un-plated veneer, which indicates wood is a kind of porous material which the surface is very coarse. It is known that there is macro-connection except intramolecular interaction between the layer and wood surface and macro-connection forces improve with enlarging contact area. That is, the coarse surface can make the layer connected with the wood surface firmly, so wood surface structure is beneficial to electroless plating. It is observed from the micrographs of plated veneer in different amplified times that the surface of wood veneer is covered entirely with very uniform and successive layer not only on the raised part but on inner layer of cell wall, which makes wood surface more like metal and give wood more beautiful appearance. The layer of very thin thickness can not caulk apetures in the surface so that it is also found that the surface of the plated veneer has the similar porous structure as that of un-plated one.

Effect of phosphorous content on surface resistivity

In this study, the layer composition is Ni-P alloy layer because $NaH_2PO_2 \cdot H_2O$ was used as the reduction agent in plating solution. In general, pH value is the key of many factors which affect the phosphorous content in the deposition of nickel. Ni-P alloy layers with different phosphorous content were prepared by using plating solutions of different pH value. The phosphorous content affects not only the microstructure but also the properties of Ni-P alloy. Sample with low phosphorous content plating layer has less surface resistivity but higher electro-conductivity. With phosphorous content increasing, surface resistivity increases both in parallel fiber direction and across fiber direction. However, surface resistivity in parallel fiber direction is less than that across fiber direction. Because current runs longer way across fiber direction than in parallel fiber direction, the surface resistivity across fiber is more than that in parallel fiber direction. The results show that its surface resistivity is lower than 0.5 Ω/□ when The phosphorous content is less than 2.37 wt pct in the layer (Fig. 6).



A B C

Fig. 5 Scanning electron microscopy views of un-plated and plated veneers

Notes: A--Profile of the surface of un-plated veneer. B--Deposited metal at raised part of cell wall. C--Deposited metal on inner layer of cell wall.

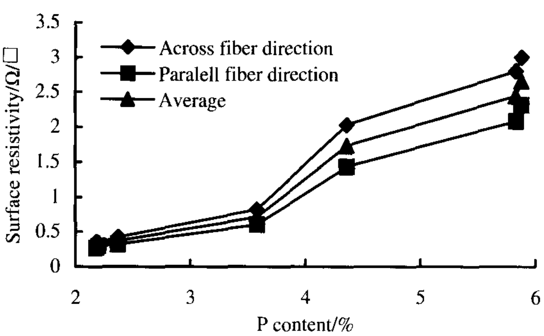


Fig. 6 Relationships between surface resistivity and phosphorous content of the plating layer

Shielding effectiveness of electroless plated larch veneer

As shown in Fig. 7, with phosphorous content in the layer decreasing, shielding effectiveness improves. When the phosphorous content decreases from 5.58% to 3.58%, shielding effectiveness improves in small step. However, shielding effectiveness improves noticeably when The phosphorous content decreases from 3.58% to 2.37%. And then, shielding effectiveness improved little when the phosphorous content decreases from 2.37% to 2.20% or 2.18%. Less phosphorous content layer has lower surface resistivity and higher electro-conductivity, which can reflect more electromagnetic waves back to air. And only a small part of electromagnetic waves penetrate the larch veneer plated with Ni-P alloy layer. It was suggested that if 40dB shielding from 30 to 300MHz was obtained, higher shielding effectiveness would be expected, and this would suffice for 95% of current commercial applications (Nagasawa *et al.* 1999).

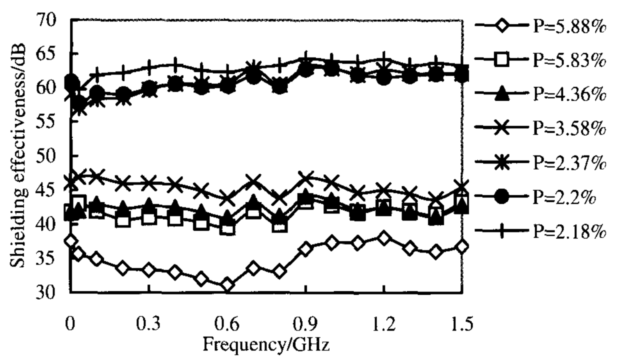


Fig. 7 Shielding effectiveness of plated larch veneer with plating layers of different phosphorous content

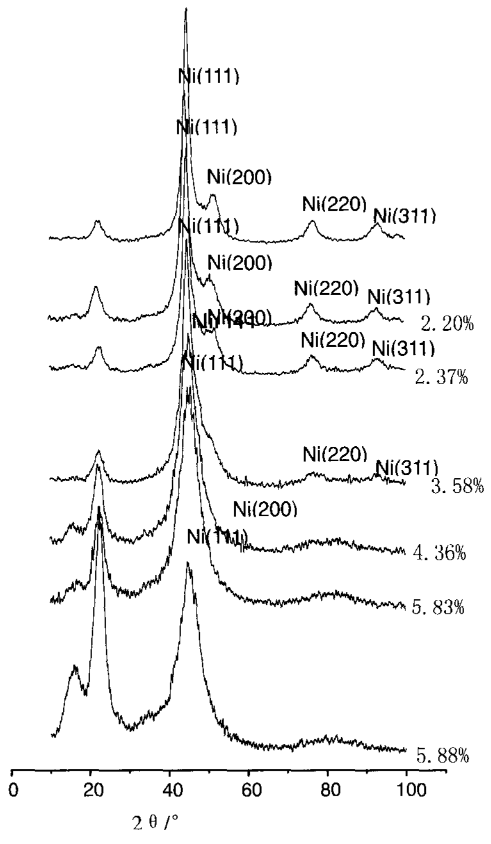


Fig. 8 XRD of the Ni-P alloy layers with different phosphorous content

The microstructure of Ni-P alloy layer on the surface of plated veneer

An acute XRD pattern from Ni(111) appears for the layer containing 5.58 wt pct P at the angle of 2θ=44. 7°. This feature indicates that the Ni-P alloy layer is composed of very small grains with a preferred orientation (Zhang *et al.* 1996). An acute XRD pattern from Ni(111) and two faint XRD peaks from Ni(220) and Ni(311) at the angles of 2θ=44. 5°, 76.4° and 92.9° appear when the coating contains 3.58wt pct P. This indicates that is a microcrystalline structure with small grains. The diffraction lines for Ni(111), Ni(200), Ni(220) and Ni(311) are well developed in the alloy layer containing 2.37, 2.20 and 2.18 wt pct P, which indicates that the low P layer is a microcrystalline structure. So decreasing phosphorous content can make the Ni-P alloy layer transform to microcrystalline structure, which endows the layer better electro-conductivity and electromagnetic shielding effectiveness (see Fig. 8).

Conclusions

(1) After plated, veneer surface is covered entirely with very uniform and successive layer on not only the raised part but also inner layer of cell wall.

(2) With phosphorous content increasing, surface resistivity increases. The plated veneer surface is anisotropic in electro-conductivity. The surface resistivity across fiber is more than that in parallel fiber direction.

(3) Plated larch veneer with less phosphorous content shows higher shielding effectiveness than the one with higher phosphorous content. Plated veneer with low surface resistivity has higher effectiveness for electromagnetic radiation.

(4) Decreasing phosphorous content can make the Ni-P alloy plating layer transform to microcrystalline structure, which endows the plating layer better electro-conductivity and electromagnetic shielding effectives.

(5) Surface resistivity of wood -Ni-P Composite by electroless plating is less than 0.5Ω/□ and its electromagnetic shielding effectiveness is up to 60dB at frequencies from 9kHz to 1.5GHz.

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